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ORIGINAL RESEARCH

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Assessing the risk of metabolic syndrome and diabetes in relation to Hookah smoking: Evidence from a cohort study in Southern Iran

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Abstract

Background: Hookah smoking has pointedly increased worldwide and could have different harmful health effects. However, long term hookah smoking effects on chronic diseases has not been well studied. This study was aimed to investigate the relationship between hookah smoking with metabolic syndrome and diabetes.

Methods: In this prospective study, the baseline data from 3695 participant (35–70 years old) of Bandar-e-Kong cohort study in Hormozgan province, Iran were used. In this study, data were collected through the questionnaires designed in the Kong cohort study and 25 mm of blood sample. All analyses were performed using SPSS version 27.0 and the ggplot2 package in RStudio version 2023.06.1 + 524. $p < 0.05$ was considered a significant difference.

Results: The prevalence of hookah smoking was 17.3% in total. Also, the prevalence of metabolic syndrome, diabetes, hypertension, and dyslipidemia were 35.6, 15.2, 31.2, and 78.0%, respectively. Our results showed that there were statistically significant relationship between hookah smoking and metabolic syndrome, hypertension and diabetes ($p < 0.05$). In the case of dyslipidemia, hookah smoking was also associated with increase in dyslipidemia ($p < 0.05$).

Conclusions: More evidence is needed to understand the mechanism of hookah smoking and these health effects. As well as, health education and increasing public awareness about the health effects of hookah smoking and implementation of smoking prohibition policies are highly recommended.

KEYWORDS

bandar-e-kong cohort study, diabetes, hookah smoking, metabolic syndrome

1 | BACKGROUND

Although cigarette smoking is the dominant form of tobacco use in many countries, hookah smoking (waterpipe, shisha, narghile, arghile, oriented pipe, and hubble bubble) accounts for a significant and growing share of tobacco use globally.[1] Hookah has been used in the Middle East for centuries.[2] Hookah use has been raised as an important problem in Arabian countries, Turkey and Iran.[3–9] According to a review study in 2022, the prevalence of hookah consumption in the world was 9.6%, with the Eastern Mediterranean region (10.7%) having the highest prevalence after Europe (10.9%).[10] The prevalence of hookah smoking has increased significantly in Iran: form 0.2% in 2016 to 4.5% in 2021.[5,11] Also, Hormozgan province with a prevalence of 30.6% has the fourth rank of hookah smoking in Iran.[12]

The hookah smoking leads to a high volume of smoke that contains 80 times more toxic chemicals than cigarette smoke.[13] Hookah smoke contains higher levels of carbon monoxide (CO) and polyaromatic hydrocarbons than cigarettes, which enter the body and accumulate there[14] and led to different cancers.[15] In addition, hookah smoking is usually associated with long-term sitting in cafes, which leads to inactivity and increased food consumption and obesity.[16] Obesity makes people susceptible to noncommunicable diseases such as diabetes and metabolic syndrome.[17]

Metabolic syndrome is associated with various symptoms such as increased abdominal obesity, increased blood pressure, decreased high-density lipoprotein (HDL) cholesterol, increased serum triglycerides, and increased glucose concentration.[18] Metabolic syndrome leads to increased risk of cardiovascular diseases, cancer and type 2 diabetes.[19] Obesity is a common feature in people with metabolic syndrome[18] and is closely related to insulin resistance and the development of type 2 diabetes.[20] The type 2 of diabetes is one of the complications of obesity and metabolic syndrome with similar causes and underlying pathophysiology, which is clinically characterized by hyperglycemia caused by insulin resistance.[21] Metabolic syndrome as a global health problem affects 8.8% of people worldwide.[22] However, 38% of the Iranian population have metabolic syndrome.[23] Although the effects of cigarette smoking on health including metabolic syndrome[24] and diabetes[25–28] have been well studied, limited studies have focused on the relationship between hookah use and metabolic syndrome and diabetes.[18,29–31] Limited studies have been conducted in worldwide with different sociodemographic characteristics, or in the central and Eastern of Iran[18,19] where hookah use and metabolic syndrome have a low prevalence, or specific populations such as patients.[20]

Considering the prevalence of unhealthy lifestyles including inactivity and unhealthy diet in Hormozgan region,[21] as well as the high prevalence of hookah and cigarette smoking,[22,23] more evidence is needed to better understand and confirm the relationship between hookah use and non-communicable diseases such as diabetes and metabolic syndrome. Therefore, this study was aimed to investigate the relationship between hookah smoking with metabolic syndrome and diabetes.

2 | MATERIALS AND METHODS

2.1 | Study design

This prospective study obtained its data from Bandare-Kong Non-Communicable Diseases (BKNCD), which is part of the Prospective Epidemiological Research Studies in IRAN (PERSIAN).[32] According to the Kong cohort protocol, the inclusion criteria was the age range of 35–70 years. In this study, census method was used to collecting data. we analyzed the baseline sample that was enrolled in October 2016, and the participants were scheduled to be re-evaluated every 5 years, with an annual follow-up. Exclusion criteria were incomplete records and pregnant women. Details of inclusion and exclusion of participants are shown in Figure 1.

2.2 | Data collection

In this study, data were collected through the questionnaires designed in the Kong cohort study, which is registered in the system, by a fully trained and experienced person by visiting the place of the Kong study and face-to-face interviews. Sociodemographic data were collected using face-to-face interviews by trained interviewers. The participants were asked to attend the next stage fasting. To collect biological samples, 25 mm of blood was collected from each individual using Vacutainers (Greiner Bio-One International GmbH). Then the blood was centrifuged and divided into different amounts and stored in a freezer (−70°C) after labeling.

2.3 | Definition of variables

In this study, diabetes was defined as FBG ≥ 126 mg/dL or treated with oral hypoglycemic drugs and/or insulin. As well as, the presence of metabolic syndrome was determined using the International Diabetes Federation criteria.[30] To diagnose hypertension (HTN), the Joint National Committee on Prevention, Diagnosis, Evaluation, and Treatment (JNC-7) classification was used.[31] Accordingly, people who had a systolic blood pressure of 140 mmHg or more, and/or a diastolic blood pressure of 90 mmHg or more were considered hypertensive. People taking antihypertensive drugs were also considered to have HTN. Dyslipidemia was defined as TC ≥ 200 mg/dL (5.18 mmol/L), or LDL-C ≥ 130 mg/dL (3.36 mmol/L), or TG ≥ 150 mg/dL (1.69 mmol/L), or HDL-C < 40 mg/dL (1.03 mmol/L) in men and <50 mg/dL (1.30 mmol/L) in women.[32] To assess whether participants had experienced hookah smoking or not, a question was used: "Have you ever smoked hookah in your lifetime?" Which answer category was "Yes or No."

3 | ETHICAL CONSIDERATIONS

The Ethics Committee of the Hormozgan University of Medical Sciences approved this study (Ethics code: IR.HUMS.REC.1402.317) which is in compliance with the statements of the

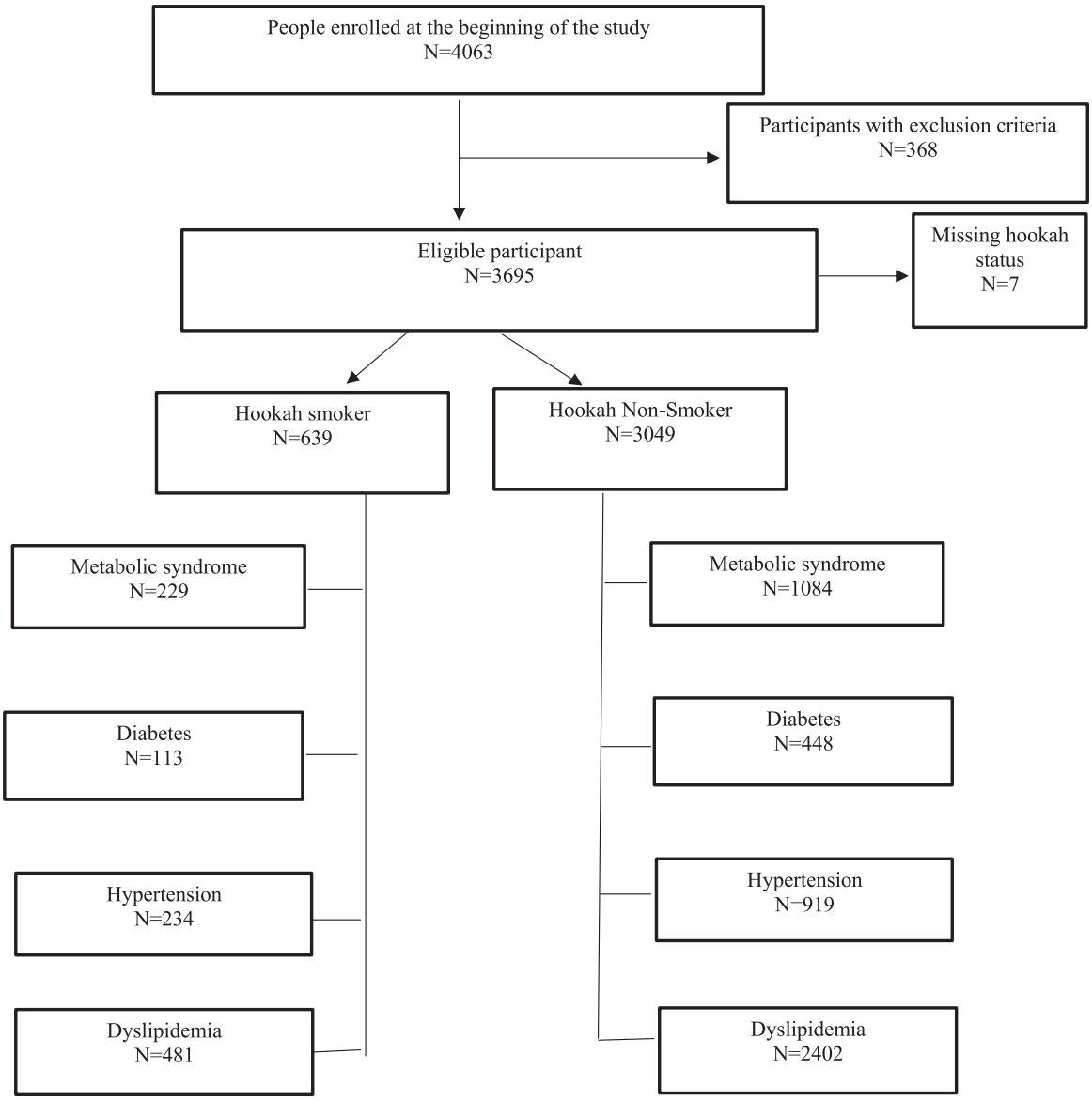

FIGURE 1 Details of participant's inclusion, exclusion, and analysis.

Declaration of Helsinki. Informed consent was obtained from all participants.

3.1 | Statistical analysis

Continuous variables were compared using Student's *t*-test and expressed as mean ± standard deviation (SD) and categorical variables were compared using the Chi-squared test and presented as frequencies (percentage). The aim of this study is to investigate the relationship between hookah smoking and each of four dependent variables metabolic syndrome, diabetes, hypertension, and dyslipidemia. Therefore, we used univariable and multivariable logistic regression models. In univariable analysis, we explored the association of explanatory variables with each dependent variable. In multivariable analysis, we had three logistic regression models based on three sets of adjusted covariates. Model 1, adjusted for age and sex. In Model 2, depending on the response, for each dependent variable (metabolic syndrome, diabetes, hypertension and dyslipidemia), the adjusted covariates included age, sex, and 3 of the 4 aforementioned variables. For example, when metabolic syndrome was a dependent variable, the adjusted covariates included age, sex, obesity, diabetes, hypertension, and dyslipidemia, and Model 3 was applied based on Model 2 adjusted for region of residence, education level, and physical activity. Crude odds ratio (cOR), adjusted odds ratio (aOR), and 95% confidence intervals (CIs) were calculated to assess the strength of the relationship between the explanatory and dependent variables. All analyses were performed using SPSS version 27.0 and the ggplot2 package in RStudio version 2023.06.1 + 524. For statistical analyses using the two-sided test, $p < 0.05$ was considered a significant difference.

4 | RESULTS

4.1 | Baseline characteristics

The baseline characteristics of total study population ($n = 3695$) are presented in Table 1. Among the participants of 44.1% were male and 55.9% were women. The mean age of total participants was 48 ± 9.36 years and there was no significant difference in mean ages of men and women. The prevalence of hookah smoking was 17.3% in total, 22.7% in men and 13.1% in women. Also, the prevalence of metabolic syndrome, diabetes, hypertension, and dyslipidemia were 35.6%, 15.2%, 31.2%, and 78.0% respectively. The percentage of diabetes, dyslipidemia, hypertension, and metabolic syndrome based on hookah smoking are shown in Figure 2.

4.2 | Metabolic syndrome

The results of univariable and three multivariable logistic regression models when the metabolic syndrome was used as the dependent variable are summarized in Table 2. According to the univariable model, the relationship between hookah smoking and metabolic syndrome was significant (cOR = 1.32, 95% CI: 1.08–1.51, $p = 0.003$). For example, the odds of metabolic syndrome in people who used hookah was 32% higher than their counterparts. Also, all other variables (age, sex, obesity, education, hypertension, diabetes, dyslipidemia, and physical activity) had a significant relationship with the metabolic syndrome. The effect of hookah use remains significant in all three multivariable models when the effects of other covariates were adjusted. After adjusting all covariates, in Model 3, there were no significant

TABLE 1 Baseline characteristics of study population.

Variables Continuous		Total ($n = 3695$) (Mean ± SD)	Male ($n = 1628$) (Mean ± SD)	Female ($n = 2067$) (Mean ± SD)	p Value[a]
Age	(In year)	48.05 ± 9.36	48.15 ± 9.5	47.98 ± 9.2	0.571
Categorical		*N* (%)	*N* (%)	*N* (%)	
Residence	Urban	3140 (85)	1407 (86.4)	1733 (83.8)	0.029
	Rural	555 (15)	221 (13.6)	334 (16.2)	
Education level	<6 years	2167 (58.6)	710 (43.6)	1457 (70.5)	<0.001
	6–12 years	120 (0.7)	720 (44.2)	490 (23.7)	
	>12 years	319 (8.6)	198 (12.2)	120 (5.8)	
Physical Activity	Low	1230 (33.3)	550 (33.8)	680 (32.9)	<0.001
	Moderate	1235 (33.4)	485 (29.8)	750 (36.3)	
	Vigorous	1230 (33.3)	593 (36.4)	637 (30.8)	
Obesity	Normal and underweight	1371 (37.1)	731 (44.9)	640 (31)	<0.001
	Overweight	1438 (38.9)	632 (38.8)	806 (39)	
	Obese	886 (24)	265 (16.3)	621 (30)	
Hookah	No	3049 (82.7)	1256 (77.3)	1793 (86.9)	<0.001
	Yes	639 (17.3)	369 (22.7)	270 (13.1)	
Metabolic Syndrome	No	2381 (64.4)	1128 (69.3)	1253 (60.6)	<0.001
	Yes	1313 (35.6)	500 (30.7)	814 (39.4)	
Diabetes	No	3134 (84.8)	1423 (87.4)	1711 (82.8)	<0.001
	Yes	561 (15.2)	205 (12.6)	356 (17.2)	
Hypertension	No	2539 (68.7)	1123 (69)	1416 (68.6)	0.807
	Yes	1153 (31.2)	505 (31)	648 (31.4)	
Dyslipidemia	No	812 (22)	438 (26.9)	374 (18.1)	<0.001
	Yes	2883 (78)	1190 (73.1)	1693 (81.9)	

[a] p Values are formed from the results of independent samples t-test for Age and Chi-squared test for categorical variables.

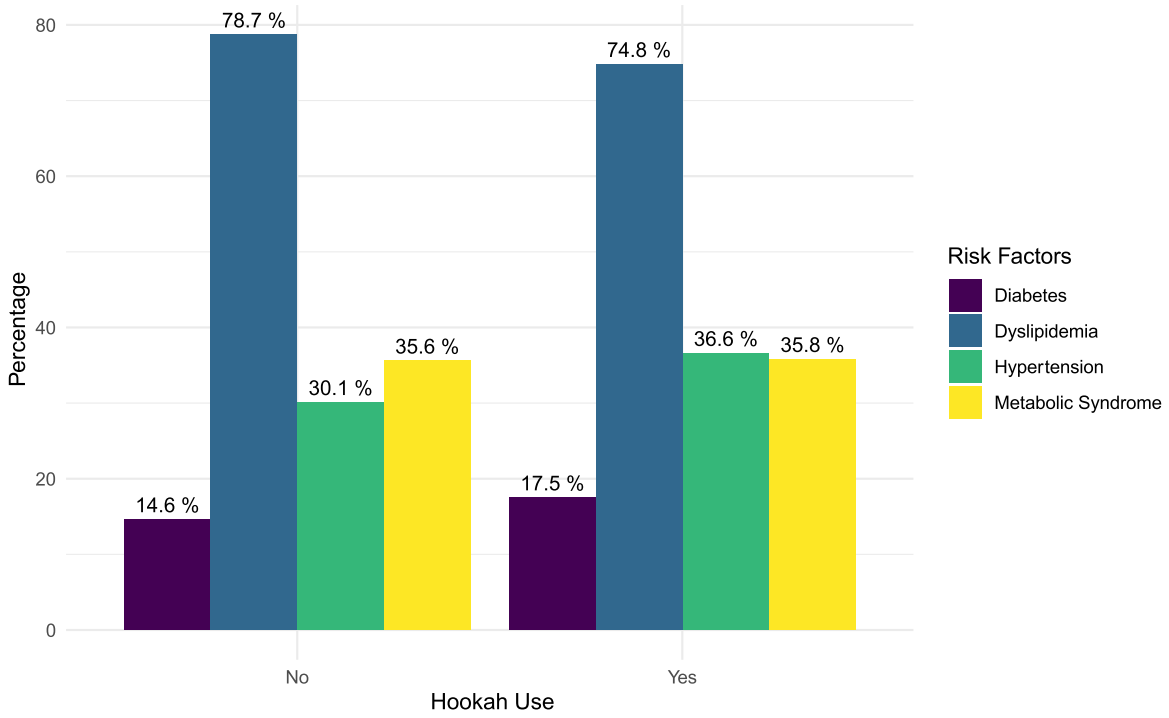

FIGURE 2 The percentage of diabetes, dyslipidemia, hypertension, and metabolic syndrome based on hookah use.

effects of sex, education levels, and physical activity. While, the odds of metabolic syndrome in people who used hookah was almost two times higher than their counterparts (aOR = 1.89, 95% CI: 1.70–2.14, $p < 0.001$). The odds of obese people to have metabolic syndrome is significantly higher than normal and underweight group (aOR = 13.031, 95% CI: 9.96–17.04, $p < 0.001$). Also, the overweight people had a significantly higher odds of metabolic syndrome than normal and underweight group (aOR = 4.809, 95% CI: 3.79–6.09, $p < 0.001$). Having diabetes, hypertension, and dyslipidemia increase the odds of metabolic syndrome (aOR = 9.35, 95% CI: 7.08–12.35, $p < 0.001$), (aOR = 7.05, 95% CI: 5.73–8.66, $p < 0.001$), and (aOR = 7.03, 95% CI: 5.23–9.44, $p < 0.001$) times respectively.

4.3 | Diabetes

Hookah use had significant effect on diabetes both in the univariable and multivariable models. In other univariable models there were significant associations between independent variables and diabetes except the region of residence ($p = 0.163$). In Model 3, after adjusting other variables, the odds of diabetes in people with hookah use was 57% higher than their counterparts (aOR = 1.57, CI: 1.36–1.89, $p < 0.001$). People who had vigorous and moderate physical activity, respectively had 32% (aOR = 0.68, CI: 0.53–0.87, $p = 0.002$) and 35% (aOR = 0.65, CI: 0.51–0.83, $p = 0.001$) lower odds of diabetes than who had low physical activity (Table 3). While variables hypertension, region of residence, and education level had no significant effect on diabetes.

4.4 | Hypertension

Hookah smoking increased the odds of hypertension significantly by 34% in the univariable model (cOR = 1.34, 95% CI: 1.12–1.60, $p = 0.001$). Also, by controlling sex and age in model 1, the odds hypertension in people who use hookah was 54% higher than people who did not use hookah (aOR = 1.54, 95% CI: 1.29–1.86, $p < 0.001$). Whereas the effect of hookah was not significant in multivariable models 2 and 3. The odds of diabetes were not different in men and women in the univariable model (cOR = 1.02, 95% CI: 0.88–1.17, $p = 0.816$) and Model 1 (aOR = 1.04, 95% CI: 0.89–1.22, $p = 0.574$), while after adjusting other covariates, the variable of sex had a statistically significant effect and women had higher odds of hypertension than men in multivariable models 2 and 3. Higher levels of education and physical activity cause lower odds of hypertension in models 2 and 3. The odds of hypertension in people who had metabolic syndrome were 6.86 times the odds of hypertension in people who did not have metabolic syndrome (Table 4).

4.5 | Dyslipidemia

Hookah smoking significantly increased the odds of dyslipidemia by 80% in the univariable model (cOR = 1.80, 95% CI: 1.36–1.98, $p < 0.001$). Whereas the effect of hookah smoking was not significant in multivariable models. Metabolic syndrome had an enormous significant effect on dyslipidemia in the Model 3 (aOR = 5.75, 95% CI: 4.39–7.55, $p < 0.001$). Physical activity did not have a significant

TABLE 2 Univariable and multivariable logistic models to investigate the association of independent variables with metabolic syndrome.

		Univariable Model				Multivariable Models											
						Model 1				Model 2				Model 3			
			95%CI for OR				95%CI for OR				95%CI for OR				95%CI for OR		
Variables		cOR[a]	Lower	Upper	*p* Value	aOR[b]	Lower	Upper	*p* Value	aOR[b]	Lower	Upper	*p* Value	aOR[b]	Lower	Upper	*p* Value
Hookah	Yes	1.32	1.08	1.51	0.003	1.914	1.757	2.103	<0.001	1.902	1.708	2.149	<0.001	1.895	1.701	2.143	<0.001
Age		1.06	1.05	1.07	<0.001	1.06	1.052	1.068	<0.001	1.033	1.022	1.045	<0.001	1.035	1.023	1.047	<0.001
Sex	Female	1.47	1.28	1.68	<0.001	1.506	1.305	1.738	<0.001	0.989	0.822	1.191	0.91	0.999	0.819	1.219	0.992
Obesity	Obese	8.45	6.91	10.32	<0.001					12.871	9.861	16.8	<0.001	13.031	9.966	17.04	<0.001
	Overweight	3.93	3.27	4.71	<0.001					4.755	3.754	6.022	<0.001	4.809	3.792	6.098	<0.001
Diabetes	Yes	9.27	7.47	11.49	<0.001					9.459	7.167	12.483	<0.001	9.352	7.083	12.349	<0.001
Hypertension	Yes	8.12	6.94	9.50	<0.001					7.158	5.83	8.789	<0.001	7.047	5.734	8.661	<0.001
Dyslipidemia	Yes	4.63	3.73	5.73	<0.001					6.844	5.104	9.178	<0.001	7.029	5.232	9.444	<0.001
Residence	Rural	1.24	1.03	1.49	0.023									1.428	1.104	1.847	0.007
Education	>12 years	0.525	0.40	0.68	<0.001									0.859	0.686	1.076	0.185
	6–12 years	0.592	0.51	0.69	<0.001									1.014	0.816	1.261	0.899
PA	Vigorous	0.55	0.46	0.65	<0.001									1.031	0.717	1.483	0.868
	Moderate	0.77	0.65	0.90	0.001									1.136	0.905	1.426	0.271

Note: Model 1: adjusted for age and sex. Model 2: Model 1 adjusted for obesity, diabetes, hypertension, and dyslipidemia. Model 3: Model 2 adjusted for residency area, education level, and physical activity (PA). Reference categories: normal and underweight group in obesity variable, urban in residence, lower than 6 years in education, low in PA, male in sex, no in other variables. Dependent Variable: metabolic syndrome.

Abbreviation: CI, confidence interval.

[a]crude OR in the univariable logistic model;

[b]adjusted OR in multivariable logistic models 1, 2, and 3.

TABLE 3 Univariable and multivariable logistic models to investigate the association of independent variables with diabetes.

		Univariable Model				Multivariable Models											
						Model 1				Model 2				Model 3			
			95%CI for OR				95%CI for OR				95%CI for OR				95%CI for OR		
Variables		cOR[a]	Lower	Upper	*p* Value	aOR[b]	Lower	Upper	*p* Value	aOR[b]	Lower	Upper	*p* Value	aOR[b]	Lower	Upper	*p* Value
Hookah	Yes	1.25	1.09	1.56	0.008	1.37	1. 42	1.67	0.005	1.58	1.39	1.90	<0.001	1.57	1.36	1.89	<0.001
Age		1.08	1.07	1.09	<0.001	1.08	1.069	1.09	<0.001	1.052	1.04	1.064	<0.001	1.049	1.036	1.063	<0.001
Sex	Female	1.45	1.21	1.75	<0.001	1.556	1.279	1.893	<0.001	1.364	1.102	1.687	0.004	1.381	1.101	1.731	0.005
Obesity	Obese	1.53	1.21	1.95	<0.001					0.576	0.427	0.777	<0.001	0.544	0.401	0.737	<0.001
	Overweight	1.52	1.23	1.89	<0.001					0.771	0.594	1.001	0.051	0.758	0.582	0.986	0.039
Metabolic syndrome	Yes	9.27	7.47	11.49	<0.001					9.297	7.062	12.238	<0.001	9.314	7.069	12.274	<0.001
hypertension	Yes	3.92	3.25	4.72	<0.001					1.186	0.943	1.491	0.145	1.17	0.929	1.474	0.182
dyslipidemia	Yes	1.41	1.12	1.87	0.004					0.686	0.517	0.911	0.009	0.696	0.523	0.927	0.013
Residence	Rural	1.19	0.93	1.51	0.163									0.919	0.692	1.219	0.557
Education	>12 years	0.34	0.22	0.53	<0.001									0.767	0.469	1.256	0.291
	6–12 years	0.55	0.45	0.68	<0.001									1.075	0.826	1.4	0.59
PA	Vigorous	0.50	0.40	0.62	<0.001									0.677	0.526	0.871	0.002
	Moderate	0.56	0.45	0.69	<0.001									0.652	0.512	0.832	0.001

Note: Model 1: adjusted for age and sex. Model 2: Model 1 adjusted for obesity, metabolic syndrome, hypertension, and dyslipidemia. Model 3: Model 2 adjusted for residency area, education level, and physical activity (PA). Reference categories: normal and underweight group in obesity variable, urban in residence, lower than 6 years in education, low in PA, male in sex, no in other variables. Dependent Variable: diabetes.

Abbreviation: CI, confidence interval.

[a]crude OR in the univariable logistic model;

[b]adjusted OR in multivariable logistic models 1, 2, and 3.

TABLE 4 Univariable and multivariable logistic models to investigate the association of independent variables with hypertension.

		Univariable Model				Multivariable Models											
						Model 1				Model 2				Model 3			
			95%CI for OR				95%CI for OR				95%CI for OR				95%CI for OR		
Variables		cOR[a]	Lower	Upper	*p* Value	aOR[b]	Lower	Upper	*p* Value	aOR[b]	Lower	Upper	*p* Value	aOR[b]	Lower	Upper	*p* Value
Hookah	Yes	1.34	1.12	1.60	0.001	1.54	1.29	1.86	<0.001	1.12	0.902	1.391	0.303	1.05	0.844	1.307	0.661
Age		1.10	1.09	1.11	<0.001	1.099	1.09	1.108	<0.001	1.088	1.078	1.099	<0.001	1.081	1.07	1.092	<0.001
Sex	Female	1.02	0.88	1.17	0.816	1.045	0.896	1.219	0.574	0.81	0.681	0.965	0.018	0.715	0.593	0.862	<0.001
Obesity	Obese	2.1	1.74	2.54	<0.001					1.312	1.027	1.678	0.03	1.35	1.053	1.731	0.018
	Overweight	1.67	1.42	1.98	<0.001					1.211	0.982	1.492	0.073	1.245	1.008	1.537	0.042
Metabolic syndrome	Yes	8.12	6.94	9.50	<0.001					6.963	5.688	8.524	<0.001	6.865	5.603	8.411	<0.001
diabetes	Yes	3.92	3.25	4.72	<0.001					1.186	0.944	1.491	0.143	1.177	0.936	1.481	0.163
dyslipidemia	Yes	1.27	1.07	1.52	0.006					0.631	0.506	0.788	<0.001	0.629	0.503	0.786	<0.001
Residence	Rural	1.42	1.18	1.71	<0.001									1.22	0.965	1.541	0.096
Education	>12 years	0.30	0.22	0.41	<0.001									0.497	0.34	0.727	<0.001
	6–12 years	0.44	0.38	0.52	<0.001									0.765	0.619	0.946	0.013
PA	Vigorous	0.56	0.47	0.67	<0.001									0.788	0.64	0.971	0.025
	Moderate	0.71	0.60	0.84	<0.001									0.914	0.745	1.121	0.387

Note: Model 1: adjusted for age and sex. Model 2: Model 1 adjusted for obesity, metabolic syndrome, diabetes, and dyslipidemia. Model 3: Model 2 adjusted for residency area, education level, and physical activity (PA). Reference categories: normal and underweight group in obesity variable, urban in residence, lower than 6 years in education, low in PA, male in sex, no in other variables.Dependent Variable: hypertension.

Abbreviation: CI, confidence interval.

[a]Crude OR in the univariable logistic model;

[b]Adjusted OR in multivariable logistic models 1, 2, and 3.

effect on hypertension in Model 3. All other adjusted covariates in the model 3 had a significant effect on hypertension (Table 5).

5 | DISCUSSION

In this study, we found that the proportion of hookah smoking was 17.3%, the proportion of metabolic syndrome, diabetes, hypertension and dyslipidemia were 35.6, 15.2, 31.2, and 78.0%, respectively. Our results showed that there were statistically significant relationship between hookah smoking and metabolic syndrome, hypertension and diabetes. In the case of dyslipidemia, hookah smoking was also associated with increase in dyslipidemia. Based on our findings, there a statistically significant relationship between hookah smoking and metabolic syndrome. As well as, considering metabolic syndrome as a dependent variable, other variables (age, gender, obesity, education, hypertension, diabetes, dyslipidemia, and physical activity) had a significant relationship with metabolic syndrome. In the same direction, previous studies also shown that the risk of metabolic syndrome was statistically higher among smokers than nonsmokers.[24,30,31] In a population-based study by Saffar Soflaei et al. also hookah smoking was strongly associated with metabolic syndrome.[18] Other studies have also shown that cigarette smoking is significantly associated with metabolic syndrome.[33–35] In the study of Kang and Song (2015) in South Korea, it was shown that smoking was significantly higher in people with metabolic syndrome.[36] In the case of relationship between metabolic syndrome and education, level, it can be stated that with the increase in education level, the awareness of healthy lifestyle increases, which can be effective in reducing the risk factors of metabolic syndrome. On the other hand, married people are likely to have a healthier lifestyle and diet than single people.

The results of the current study also showed that there is a statistically significant relationship between hookah smoking with hypertension and diabetes. In the same direction, results of a study on the health effects of hookah smoking, showed a positive relation between hookah and diabetes,[37] as well as, hypertension was the most commonly reported health problems among the hookah smokers.[37] Previous studies showed that hookah smoking increased the hypertension and the risk of overall cardiovascular events.[38,39] The relation between cigarette smoking and diabetes is well known in previous studies, but the effects of hookah smoking have not been studied extensively.[27,40,41] In a population-based study, hookah smoking was strongly associated with diabetes mellitus.[18] Although the molecular mechanisms by which hookah smoking causes metabolic syndrome were not investigated in our study, but it can be argued that hookah smoking induces oxidative stress by affecting the activity of transcription factors and the release of stress hormones, and lead to several diseases.[42]

In our study, hookah smoking was significantly associated with increased in dyslipidemia. In a study by Chwyeed et al. (2018), hookah smoking changed lipid profile, where it increased the triglycerides and LDL levels.[43] The prevalence of dyslipidemia in smokers was also higher than non-smokers in the Kurdish population of Iran.[44] In a study in South Korean, smokers presented with a higher chance of dyslipidemia compared to nonsmokers.[45] In another study, among the boys, the HDL-C levels were significantly lower if exposed to passive secondhand smoking frequently.[46] In a study, results have shown that smoking reduces total cholesterol, LDL and HDL,[47] another has showed the increases total cholesterol, LDL-C, and triglyceride with a decrease in HDL-C levels.[48] Although this conflict has been observed after controlling for confounding factors such as age, gender and BMI,[49] which difference in results can be due to differences in diet or weather conditions in the studied populations. As well as, these conflicts could be due to the association between serum lipids levels and other factors such as the use of alcohol consumption, diet, physical activity, and consumption of various tobacco products. In general, our findings regarding the harmful health effects of hookah smoke chemicals are biologically acceptable with different points of view. The biological mechanisms responsible for the effects of hookah smoking on the biochemical data of smokers are clear.

Hookah smoking has strangely increased globally mainly among younger people. Regarding the confirmed harmful health effect in our study, as well as previous studies, hookah smoking will pose different health consequences due to chronic exposure. Along with proving the association between hookah smoking and metabolic conditions, it is necessary to take more comprehensive public health measures to reduce its use. Longitudinal studies on different age groups and different types of tobacco products available in the market can provide appreciated insights on this topic and guide the development of this public strategy. There are beliefs that hookah smoking is harmless compared to cigarettes; which health education and increasing public awareness (all age groups) about the health effects of hookah smoking are highly recommended to change of this incorrect view.

The main strength of our study is its population-based project and a fairly large sample (n = 3695) to examine relationships between hookah smoking and metabolic syndrome. Our study has also some limitations which need to be specified. First, our study was only conducted in one province of Iran and results may not be generalizable to other provinces/areas of this country. Second, the question related to the use of hookah was answered as “yes or no” and the participants did not report the duration and frequency and/or times of smoking per day. Therefore, failure to mention the duration, number and frequency of hookah smoking per day/week can affect our results. This study did not include individuals under 35 and over 70 years of age. Therefore, the results could not be generalized to all age groups. Finally, participants of this study no mentioned used to traditional hookah or fruit-favorited hookah, which the type of tobacco used may affect our results.

6 | CONCLUSION

In conclusion, hookah smoking have significant relationship with metabolic syndrome, diabetes, hypertension and dyslipidemia in participants of Kong cohort study. More evidence is needed to

TABLE 5 Univariable and multivariable logistic models to investigate the association of independent variables with dyslipidemia.

		Univariable Model				Multivariable Models											
						Model 1				Model 2				Model 3			
			95%CI for OR				95%CI for OR				95%CI for OR				95%CI for OR		
Variables		cOR[a]	Lower	Upper	*p* Value	aOR[b]	Lower	Upper	*p* Value	aOR[b]	Lower	Upper	*p* Value	aOR[b]	Lower	Upper	*p* Value
Hookah	Yes	1.80	1.36	1.98	<0.001	1.043	0.688	1.073	0.099	1.06	0.712	1.09	0.243	1.072	0.703	1.092	0.214
Age		1.01	1.00	1.02	0.024	1.011	1.002	1.019	0.014	1.007	0.997	1.017	0.167	1	0.989	1.011	1
Sex	Female	1.67	1.43	1.95	<0.001	1.644	1.403	1.926	<0.001	1.435	1.214	1.696	<0.001	1.307	1.095	1.559	0.003
Obesity	Obese	2.59	2.08	3.21	<0.001					1.407	1.106	1.789	0.005	1.351	1.06	1.721	0.015
	Overweight	2.18	1.82	2.60	<0.001					1.634	1.355	1.97	<0.001	1.629	1.349	1.967	<0.001
Metabolic syndrome	Yes	4.63	3.73	5.73	<0.001					5.63	4.299	7.374	<0.001	5.755	4.386	7.551	<0.001
diabetes	Yes	1.41	1.12	1.87	0.004					0.633	0.478	0.838	0.001	0.634	0.478	0.842	0.002
hypertension	Yes	1.27	1.07	1.52	0.006					0.607	0.488	0.754	<0.001	0.6	0.482	0.747	<0.001
Residence	Rural	0.72	0.59	0.89	0.002									0.634	0.506	0.795	<0.001
Education	>12 years	1.10	1.09	1.11	0.025									0.69	0.505	0.941	0.019
	6–12 years	1.02	0.88	1.17	<0.001									0.714	0.584	0.874	0.001
PA	Vigorous	0.763	0.632	0.921	0.005									0.877	0.716	1.073	0.203
	Moderate	1.067	0.876	1.298	0.521									1.115	0.905	1.375	0.306

Note: Model 1: adjusted for age and sex. Model 2: Model 1 adjusted for obesity, metabolic syndrome, diabetes, and hypertension. Model 3: Model 2 adjusted for residency area, education level, and physical activity (PA). Reference categories: normal and underweight group in obesity variable, urban in residence, lower than 6 years in education, low in PA, male in sex, no in other variables. Dependent Variable: dyslipidemia.

Abbreviation: CI, confidence interval.

[a]Crude OR in the univariable logistic model;

[b]Adjusted OR in multivariable logistic models 1, 2, and 3.

understand the mechanism and the effects of exposure/smoking duration between hookah smoking and these health effects. As well as, health education and increasing public awareness about the health effects of hookah smoking and implementation of smoking prohibition policies are highly recommended.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

ETHICS STATEMENT

The Ethics Committee of the Hormozgan University of Medical Sciences approved this study (Ethics code: IR.HUMS.REC.1402.317) which is in compliance with the statements of the Declaration of Helsinki. Informed consent was obtained from all participants.

TRANSPARENCY STATEMENT

The lead author Sara Dadipoor affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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